

PLANETARY SURFACE SAMPLE COLLECTION: ROCK CHIPPER

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Introduction. Among the highest priority science objectives for planetary surface exploration is measurement of the composition of surface materials, as these record chemical and physical processes that provide important insights into the climate and volatile history of a planet. Aqueously deposited minerals are potentially also important storehouses for biological information preserved as morphological and chemical fossils [1,2]. While some analytical techniques require only that material be located close enough to the instrument, others require that target material be extracted from its environment and placed into a sample chamber [3]. We report here the development of a new sample collection technology able to extract and transfer powder samples from rock, and furthermore create cm-sized, intact pieces of rock that are easily retrieved and placed into a sample cache.

New technological approaches and capabilities will be needed on future small, low cost landers [4]. In order to address overarching questions like the possible origin of life on Mars, it will not suffice merely to scoop up a soil sample for analysis, even from a carefully chosen landing site [5]. *We must instead be able to survey a site, find and identify the important rocks and soils deserving further analysis, and then we must be able to obtain scientifically useful samples of both rocks and soil.* Both for geological/geophysical exploration and for exobiology, we need capability to sample rock, and we need access both to the subsurface regolith and to rock interiors.

The most fundamental requirements are to obtain sufficient sample mass, to minimize contamination of sample, and to minimize size, cost, and complexity of the sampling instruments. Also key, however, is the need to obtain samples in the proper physical form, that is, as well-mixed powder or as intact rock chips of adequate (cm) size. For *in situ* mineralogical and chemical analysis, some techniques like x-ray diffraction require powder samples [3]. However, for return of samples to Earth, intact rock pieces are preferable [6]. If there are tight constraints on the total mass returned to Earth, an *in situ* analysis capability is needed to ensure that the most interesting and important rock samples are returned. Moreover, many of the important target rocks at a site are likely to be too large to be collected for sample return and will require

subsampling. Hence we need *both intact rock pieces and powder samples from the same rock.*

Planetary Instrument Definition and Development Program (PIDDP) results. Our previous PIDDP work developed prototype sample collectors that validated the concept of sampling rock or regolith targets using pyrotechnic gas generators to fire steel penetrators into the surface, obtaining core samples [7,8]. This work did not address the key issues of how to transport the samples back to a carrier vehicle, or how to extract them from the collector.

The present work developed and tested a new pyrotechnic sampler/catcher module to collect both powder samples and intact pieces of rock. Powder samples >1 gm can be obtained from solid rock or from loose regolith. The module holds the powder sample securely for transport; pours the sample out easily into a designated receiving tray; and minimizes sample contamination.

The sampler/catcher module also creates cm-sized intact chips of rock that are efficiently trapped and made readily available to be picked up and cached by a robot manipulator. The module does not need sustained power and does not require the carrier platform to be extremely stable or to exert large sustained forces.



Figure 1. Prototype sampler/catcher module.

Design. Each sampler/catcher module (Figure 1) is based on one moving part, a steel penetrator that is propelled by a pyrotechnic gas generator into the target surface, where it makes a crater. The impact creates a conical sheet of powdered ejecta at an angle of about 45° to the local surface normal, both for rock and soil targets. The ejecta cone is captured by a specially shaped container ("catcher") occupying an annulus

around the penetrator. If the sampler/catcher is fired into a dirt clod mistaken for a rock, it will still obtain a valid sample. At the same time that the penetrator extracts the powder sample, it creates the rock chips by deeply fracturing the rock. The resulting loose rock chips are trapped beneath the catcher and are not sent flying away. The rock chips pose no hazard to the vehicle and can be found easily if desired.

The penetrator is retained within the sampler housing, and the propellant is totally isolated from the sample to avoid contamination.

Function. The sampler/catcher module is designed to be placed directly in contact with the target to be sampled. No proximity detection system is required. Sample acquisition is independent of the module's precise orientation, as long as the penetrator fires generally downward.

When the sampler/catcher is inverted by the robot arm over a receiving tray, sample pours out. This design solves the problem of how to retain the powder sample securely for transfer, while at the same time permitting the sample to be removed completely and placed into a receiving tray by a simple mechanism. This sample acquisition and transfer process is accomplished using only the articulation of the robotic arm that manipulates the sampler/catcher. Figure 1 shows the prototype unit being held by the catcher; the hole near the bottom of the catcher is where the powder sample pours out.

The sampler/catcher samples a rock surface and the interior to a depth of about 1 cm and removes the weathering rind over a surface area $>15 \text{ cm}^2$. If rock chips can be cleared from the sampling site by a robot manipulator, the freshly exposed area is much greater.

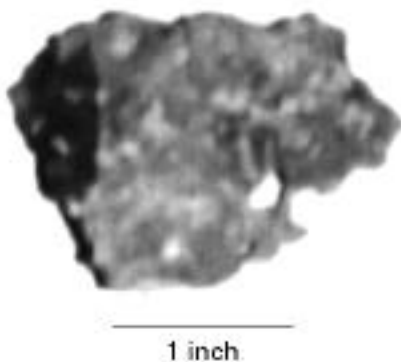


Figure 2. Intact basalt chip extracted by sampler/catcher.

Figure 2 shows an example of an intact chip extracted by the sampler/catcher from a large basalt rock. It was easily dislodged by hand and could have

been picked up and cached by a robot manipulator. This chip has a maximum diameter of 2.2 inches and is more than adequate for sample return; smaller chips were also created in the same shot. A weathering rind can be seen over most of the right side in Figure 2; the darker area is fresh interior, and the penetrator impacted near the left edge in the figure.

We are performing laboratory analyses of the basalt powder sample poured out of the sampler/catcher after the shot that created the chip in Figure 2. The particle size distribution extends from a few mm down to microns. The sample has also been evaluated for evidence of contamination. Figure 3 shows a powder sample extracted from hardened, reinforced concrete, next to an inch ruler for scale. Intact pebbles of 0.2 inch or larger are present.

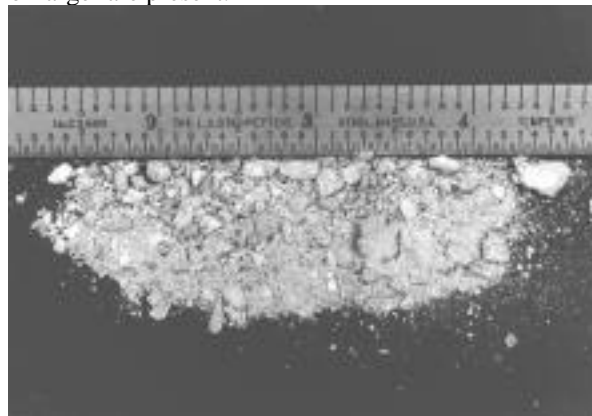


Figure 3. Powder sample (4 gram) extracted by sampler/catcher from reinforced concrete target.

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